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SOME RELATIONSHIPS BETWEEN TREE RESPONSE AND INTERNAL COMPOSITION OF SHOOTS OF THE PEACH

A PART OF A DISSERTATION SUBMITTED TO THE FACULTY OF THE DIVISION OF THE BIOLOGICAL SCIENCES IN CANDIDACY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF BOTANY
1931

By
FRANK PATRICK CULLINAN

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Some Relationships Between Tree Response and Internal Composition of Shoots of the Peach[1]

By F. P. CULLINAN,[2] *Purdue University, Lafayette, Ind.*

PEACH trees show a marked response to environmental changes as a result of the horticultural practices of pruning and orchard fertilization. By varying the environmental conditions in which the tree is growing, the amount of terminal shoot extension may be caused to vary from a few inches to 4 or 5 feet in length.

In some peach pruning experiments, it has been observed that the number of blossom buds per shoot may vary with the quality of shoot growth produced (1). It has also been observed that the blossom buds produced on shoots differing in length and diameter may vary in their hardiness with respect to low winter temperatures (2). It would be of considerable interest to know whether these differences are correlated with chemical composition of the shoots and whether the factors responsible for the differences can be affected by cultural treatments.

Terminal shoots were selected in three seasons from peach trees growing in two orchards of the Purdue University Agricultural Experiment Station. Shoots of varying length were selected late in the season of 1928 and the winter and spring of 1929 from 5-year-old Elberta trees growing on a sandy loam soil and receiving varying amounts of pruning. During the season of 1929 and the winter of 1930–31 terminal shoots were selected from 6-year-old Elberta trees growing on a clay loam soil in another orchard where the quantity and quality of shoot growth were varied by applications of nitrogen to the soil. The shoots were collected at about the same time of day on each sampling date and brought to the laboratory where they were cut up into small pieces and preserved in 95 per cent alcohol. Determinations were made on dry weight, soluble and insoluble nitrogen, reducing sugars, sucrose and starch. Only a summary of the results secured will be given here.

RESULTS

Preliminary studies made on samples of terminal shoots taken in 1928–29 from trees receiving varying amounts of pruning indicated differences in the chemical composition of qualitatively different shoots. The values for total nitrogen and sugar showed an increasing gradient from base to tip of the longer branched shoots. The basal and middle portions of long shoots which formed new fruit buds were relatively low in total sugars and nitrogen. The upper middle, tip, and laterals of the 1-year shoots showed an increase in total sugars and nitrogen in the combined bark and wood as compared

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[2]Now with the U. S. Department of Agriculture.

with the basal portions. Wood and bark were not separated in these samples, and the differences may have been due in part to the relative amounts of bark and wood in the separate fractions. However, at the time of sampling in September, 1928, a comparison between laterals and short spurs of about the same dry weight, and which possessed about the same relative amounts of bark and wood in the sample, showed that short spurs contained a relatively greater amount of reducing sugars and sucrose and less soluble and insoluble nitrogen than the laterals. The short spurs contained about three times as many blossom buds as the laterals. As will be pointed out later, these values for total sugar may have been somewhat different on samples taken later in the season. The data secured indicated that peach shoots which are qualitatively and quantitatively different in length, diameter and position in the tree, exhibit considerable qualitative and quantitative variation in their chemical make-up.

In 1929 a block of 28 six-year-old Elberta peach trees growing in a clay loam soil in the Experiment Station orchard were given uniform pruning, but the amount of nitrogen fertilizer was varied. By this means it was hoped to bring about differences in length and quality of shoot growth which could be sampled during the season to study any change in internal composition. An analysis of the one-year shoots of the trees prior to the time of applying the fertilizer showed that their composition was fairly uniform and differences between plots were within the range of random sampling. None of the trees used showed any evidence of a nitrogen deficit at the beginning of these studies. The fertilizer treatments were: (1) no nitrogen; (2) moderate nitrogen,—a 3-lb. application before bloom; and (3) heavy nitrogen,—a 3-lb. application before bloom, 2 pounds after petal fall, and 2 pounds 6 weeks after petal fall. Samples of unbranched terminal shoots were selected as the unit of comparison between treatments at six different periods during the season, namely, (1) as blossoms were showing pink, (2) after petal fall, (3) seven weeks after petal fall, (4) mid-season, (5) after harvest, and (6) early winter.

In all cases where nitrogen had been supplied either before or after bloom, higher nitrogen content was noted in the new growth (Table I). Six weeks after petal fall, trees which received no nitrogen showed an appreciably smaller shoot growth than trees receiving nitrogen. The shoot growth of unfertilized trees was higher in dry weight and starch, and lower in soluble and insoluble nitrogen. By mid-season the terminal growth of the non-nitrogen trees had been completed and averaged only about one-third the length of heavy nitrogen trees. Starch continued to accumulate in the shoots of low nitrogen trees and reached its highest point in September. In late summer, starch began to accumulate in the high nitrogen trees and likewise reached its high point in September, although at that time it was less than that found in low nitrogen trees. Fruit buds were larger and more developed at this time on the non-nitrogen trees although more

numerous on the high nitrogen trees because of the greater total growth. No samples were taken between September and December, and it is not known just when starch ceased increasing. However, during this period there was marked disappearance of starch, and sugars showed an increase in the terminal shoots. Samples taken in early winter (December, 1930) showed the terminal shoots of high nitrogen trees to be slightly higher in starch than the low nitrogen trees. This may be due to the rate of hydrolysis, and it may have progressed farther on the non-nitrogen trees. The total nitrogen content of shoots receiving heavy nitrogen treatments was higher at all times throughout the season than in shoots from non-nitrogen trees.

TABLE I—Composition of Unbranched Terminal Shoots of the Peach, in Per cent of Dry Weight, 1929

Date	Rows	Material	Treatment[1]	Length (Cms.)	Dry Weight	Total Sugars	Starch	Total Nitrogen
4/8	12–13	1-yr. wood	——	40.7	44.48	3.29	2.04	.922
	14–15	1 yr. wood	——	40.3	44.14	3.04	2.71	.953
4/26	12–13	1-yr. wood	O-MP	35.7	47.23	3.17	1.91	.846
	14–16	1-yr. wood	N-MP	36.9	45.8	3.40	2.13	.870
6/14	13	New growth	O-MP	7.5	35.61	6.06	5.37	1.12
	14	New growth	N-MP	9.0	30.72	7.36	4.47	1.59
	15	New growth	HN-MP	11.2	31.10	5.54	5.09	1.54
	13	1-yr. wood	O-MP	33.6	49.1	3.50	3.66	0.65
	14	1-yr. wood	N-MP	35.4	44.3	3.58	2.61	0.76
	15	1-yr. wood	HN-MP	36.8	41.7	3.57	1.58	0.75
7/27	13	New growth	O-MP	13.5	50.8	3.62	5.60	.707
	14	New growth	N-MP	37.7	38.7	3.35	2.26	1.01
	15	New growth	HN-MP	36.7	46.4	4.19	2.84	.871
9/27	13	New growth	O-MP	10.3	45.5	3.22	8.11	.90
	14	New growth	N-MP	36.1	51.2	2.71	7.36	.78
	15	New growth	HN-MP	36.2	48.1	2.69	7.27	.95
	13	1-yr. wood	O-MP	37.0	59.5	2.77	7.95	.53
	14	1-yr. wood	N-MP	41.5	59.4	2.15	8.88	.45
	15	1-yr. wood	HN-MP	41.7	58.7	2.03	7.06	.44
12/30	13	1-yr. wood	O-MP	22.3	51.0	5.94	2.75	1.03
	14	1-yr. wood	N-MP	41.8	52.3	6.26	3.08	1.11
	15	1-yr. wood	N-HP	42.3	53.1	5.92	3.06	1.12

[1]O = No nitrogen, N = Nitrogen, HN = High nitrogen, MP = Moderate pruning.

Analyses of terminal shoots made after terminal growth had ceased on all plots (September) did not show the marked differences in composition that might have been expected from the vegetative appearance and amount of shoot growth made by trees under the various treatments. Thus in the dormant seasons of 1930 and 1931, a year of no crop, total nitrogen in the terminal shoots of non-nitrogen trees was nearly as high, and in some instances higher, than in trees receiving large applications of nitrogen fertilizer. During the period of terminal elongation, however, total nitrogen was relatively higher in

the shoots of the high nitrogen trees. During the period before leaf fall when nitrogen would be expected to move from the leaves into the shoots, the increase in nitrogen in the shoots was greater relatively on the non-nitrogen trees. The values for starch in the terminal shoots were also much closer together for the different treatments during the late fall and winter than during the growing season. Determinations were not made to study what corresponding changes were made in other parts of the tree.

TABLE II—Length of Shoots Produced on Unfertilized Trees in Two Successive Seasons

Row	Treatment	Length, 1929 (Cms.)	Length, 1930 (Cms.)
13–3	No nitrogen in 1929 3 lbs. ammonium sulphate in 1930.....	9.9	38.3
13–5	No nitrogen in 1929 3 lbs. ammonium sulphate in 1930.....	10.6	40.3
14–4	3 lbs. ammonium sulphate in 1929 No nitrogen in 1930.....	34.4	17.8
14–3	3 lbs. ammonium sulphate in 1929 No nitrogen in 1930.....	18.6	11.4
14–2	3 lbs. ammonium sulphate in 1929 No nitrogen in 1930.....	20.2	12.8

Although nitrogen was not determined in the roots and other parts of the tree in the dormant season, it is probable that the total nitrogen reserve was higher in trees well supplied with nitrogen. This is indicated by the greater terminal extension made by trees in the season following nitrogen applications. With trees receiving no nitrogen fertilizer in 1929 but an application of 3 pounds in 1930, the terminal shoot growth was increased in length nearly four times. Trees which had received nitrogen in 1929 but none in 1930 produced terminal shoots about one-half as long as in the previous season (Table II). Where the number of growing points had been reduced by pruning on similarly treated non-nitrogen trees in 1930, terminal growth was markedly increased.

Hardiness of Buds Under the Various Treatments

A temperature of —5 degrees F. occurred in December, 1929. Two weeks after the freeze, samples of terminal growth were taken for analysis. The percentage of live buds in a 100-gram sample of representative shoots taken from each plot is given in Table III. Approximately 55 per cent of the buds on short spurs and 45 per cent on the longer terminals of the non-nitrogen trees were killed, while only about 18 per cent were killed on the long terminals of the high nitrogen trees.

TABLE III—Per cent of Live Buds Found in 100-Gram Samples Taken December 30, 1929

Row	Treatment	Average Length of Shoots (Cms.)	Number Live Buds	Number Dead Buds	Per cent Live Buds
13	No nitrogen	22.3	76	60	55.9
13	No nitrogen	7.2	123	149	45.2
14	3 lbs. $(NH_4)_2SO_4$ (before bloom)	41.8	214	55	79.5
15–16	7 lbs. $(NH_4)_2SO_4$ (before and after bloom)	43.2	250	54	82.2

The chemical data (Table I) do not suggest the probable explanation for the greater hardiness of buds on the longer shoots. The only marked difference in composition between shoots from the various plots was that those shoots which bore the highest per cent of live buds were higher in reducing sugars. The longer shoots were also higher in total nitrogen throughout the growing season. Moisture content and composition of the buds were not determined. Blossom buds on the short spurs and terminals of low nitrogen trees were more developed in autumn than some buds on shoots of high nitrogen trees. Basal buds on long terminals and buds on the laterals of branched terminals were smaller in size. While it is probable that the factor or complex of factors responsible for the greater hardiness of the buds lies in the psysiochemical relationships in or near the bud rather than in the shoot as a whole, it does appear that these factors may be associated with the nutritional conditions of the tree. This may also affect the time of fruit bud differentiation in the shoot and the beginning of the period of rest.

The growth of the peach is quickly affected by changes in nutritional conditions as evidenced by the quantity and quality of growth produced with a heavy crop, when nitrogen fertilizers are withheld or when a large part of the top is removed in pruning. The data secured in these studies indicate that shoot growth may vary in internal composition under different conditions of nutrition. Further data are needed in a study of the correlation of these conditions to blossom bud formation and hardiness of buds.

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